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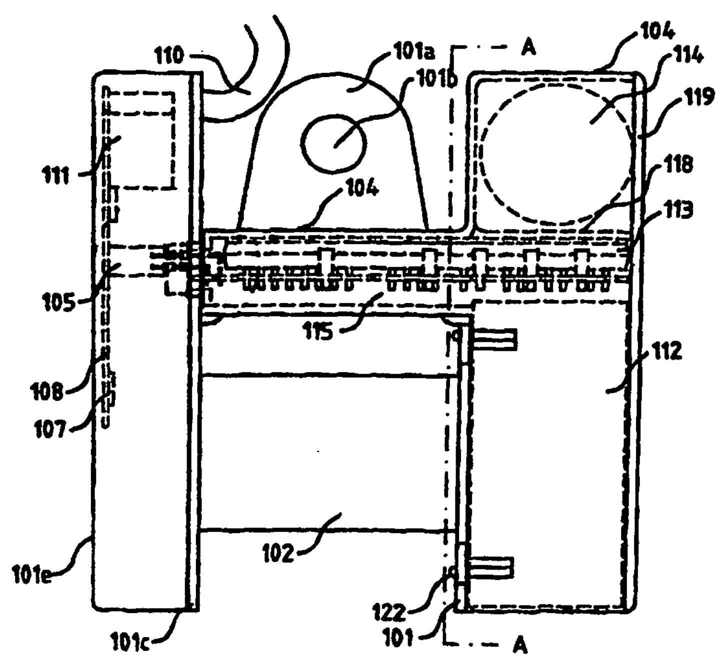
(54) Title: SEAT BELT TENSIONING SYSTEM

(57) Abstract

A conventional seat belt rolling-up frame (101) is equipped with an electric motor (112) for tensioning the seat belt both to a comfort value for normal rides and to high forces in emergency situations. The motor can be activated as often as required without any need for maintenance. The power required to drive the motor is obtained from a high voltage capacitor (114) storing sufficient energy. The seat belt will then be independent of the resistance of the starter battery of the vehicle in which the seat belt is mounted. All electronic parts connected to the stator phases of the motor and to the capacitor are contained in a shielding enclosure (104, 119, 124) resulting in low emissions of high frequency electromagnetic noise. The motor is mounted at a first end of a belt roller shaft (102) to drive this shaft directly. The mounting is made so that the motor and the shaft will be displaced by the very high belt tensions created by a serious crash. Cog means (120) can then lock the rotor of the motor and thereby the shaft. Signal processing circuits (108, 109, 107) for low voltage signals are located inside a casing (101e) attached at a second opposite end of the shaft.



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SEAT BELT TENSIONING SYSTEM

TECHNICAL FIELD

The invention is concerned with seat belt tensioning systems.

BACKGROUND OF THE INVENTION AND PRIOR ART

Seat belts or safety belts have been used for many years in different types of vehicles such as cars, trucks. Some problems associated with seat belts are as follows.

Seat belts used in cars are normally loosely tightened. This reduces the effect of the belt since a part of the potential retardation distance between the position of the passenger body during a pre-crash period and the maximum allowable position of the passenger body during the crash will be wasted before the belt will be effective in reducing the velocity of the passenger body.

This problem is today in some seat belt systems handled by a crash sensor which will detect an ongoing crash some milliseconds after the crash has started. The sensor fires a pyrotechnic cartridge which tensions the seat belt. An example given in a leaflet by the company Autoliv Inc. indicates that the crash detector (the "ECU unit") sends it firing command to the pyrotechnic belt tensioner some 12 ms after the start of the crash. Pyrotechnic belt tensioners use a cylinder and a piston and therefore have a limited stroke.

A belt tensioning system using an electric motor capable of delivering enough power to effectively replace a pyrotechnic cartridge would give much more flexibility. This is specially so if combined with a pre-crash sensor, using for example radar, artificial vision or sonar systems. It can tolerate false alarms from the sensors since the penalty would be a belt tensioned during only some milliseconds and not an exploded pyrotechnic cartridge which will require a service intervention in order to be operative again.

A belt tensioning system which can accept false alarms at a negligible cost permits the crash detection systems to give alarm earlier in the sequence of events in a crash. By using lower alarm thresholds for accelerometer type crash sensors, a high power electric belt tensioning system could start to tension the safety belt for example about 3 ms after the start of the crash. This difference from 3 to 12 ms permits a substantial action of a high power belt tensioner. As an example, a simulation shows that a safety belt having a direct driving electric motor with a 9 Nm torque in 3 ms can roll up 3 mm of safety belt and establish a force of 18 N. After 12 ms the same system has rolled up 71 mm of the belt and established a belt force of 320 N.

By using lower alarm thresholds, a pre-crash sensor could give alarms earlier in the crash sequence of events. Pre-crash sensors use less precise data than a sensor of the accelerometer type. A solid object in the driving direction might be a bus stop weather shelter located in the beginning of a curve or be a stopped car on a single lane road with deep ditches on each side. An approaching vehicle having a path indicating a collision in

500 ms will most often be a meeting car just before a road bend but might be a car with a sleepy driver. It seems likely that pre-crash sensors will for a long period have a limited capability of distinguishing between trivial harmless objects and highly dangerous objects. Alarms will therefore often arrive shortly before the crash and will often be false. This rises the need for safety belt tensioning systems which can establish a sufficient belt tension within a short time and which can be activated not requiring to be reset by a service intervention.

The use of an electric motor connected to the belt gives other advantages. It permits an individual setting of belt tension during normal rides. It permits different belt tensions before, during and after the belt is connected to the third point buckle. This permits for example a higher tension after the belt has been released from the buckle which can ensure a proper rolling-up of the belt.

A high tension in the belt can be used to send a unique signal to the driver indicating that the pre-crash sensor has detected indications of a potential crash. One such signal could be a high force belt tension. Such a signal has several advantages. Unlike warning sounds and optical alarm lamps, a high belt tension will not mask sounds and/or visual information which the driver should hear or see in order to be able to reduce the risk of a crash. It also has the advantage that it will reduce injuries if a crash would occur.

However, given the assumed complexity of making reliable pre-crash sensors as discussed above, it is likely that most users will find warnings from pre-crash sensors a stressing nuisance. To be of any use, such warnings must be given so early before the expected event that the driver has a reasonable possibility to notice the warning, to identify the problem and to act in order to avoid it. This means several hundreds of milliseconds. There are some conditions in which such warnings can be helpful, for example if a vehicle in front of the considered vehicle having the crash sensor suddenly reduces its speed and the driver of the vehicle having the crash sensor does not seem to make any suitable actions. In many other situations, a pre-crash sensor can give a relevant alarm only when the time up to the crash is far below the necessary reaction time of the driver. If most of the pre-crash situations which might result in an actual crash would cause a low level alarm, the number of alarms would be intolerable. It is therefore important that systems capable of giving high tensions in safety belts will be capable of achieving them without any required initial medium or low tension movement.

A safety belt having a processor controlled motor capable of creating various low level belt tensions has been described in U.S. patent 5,558,370. In the case where a high pretension is needed, it is arranged by exploding a pyrotechnic cartridge.

Another safety belt having a processor controlled motor capable of creating various low level belt tensions has been described in U.S. patent 5,788,281. The belt tensions given are in the order of 0 to 50 N and the belt tensions are created by an electric motor

and a spring. Medium low tension is arranged by the spring only. A no-tension state is arranged by having the electric motor torque counteracting the spring and a higher, low tension level is arranged by having the electric motor torque acting in the same direction as the spring. The system works in a number of modes having different belt tensions. An object detector determines the positions and speeds of objects close to the vehicle. Dependent thereof the belt tension is adjusted between different predetermined levels. The two highest tension levels are given as some 30 N and over 50 N.

In the published German patent application 43 32 205 A1 a safety belt is described in which various levels of low belt force are provided by an electric motor and a mechanical spring. Medium low tension is obtained from the force of the spring only. A lower, low tension level is arranged by having the electric motor torque counteracting the force of the spring and a higher, low tension level is arranged by having the electric motor torque acting in the same direction as the force of the spring. A high level pretension is arranged by making a pyrotechnic cartridge explode.

In the published German patent application 195 20 721 A1 it is stated that electric motors cannot be used in safety belt tensioning devices due to the long reaction times of such devices, supposed to be about 500 ms, but it is also suggested that electric motors could be used together with pre-crash sensors which are capable of predicting a crash at least 1/2 second before the crash.

In U.S. patent 4,579,294 a seat belt retractor is disclosed using a second spring which is released in emergency situations and which can be rewound to adopt its high tension state by energizing an electric motor.

In the published European patent application 0 813 999 A1 the use of an energy storage capacitor charged to 50 V is disclosed. The capacitor ensures that power for the ignition of air bags or pyrotechnic safety belt tension cartridges will be available even if the crash has destroyed the battery or the cabling from battery to the safety devices.

In the published International patent application WO 98/36949 a safety device controller is disclosed controlling a plurality of safety devices such as airbags, pyrotechnic seat belt tension cartridges, etc., having an energy storage capacitor typically operating at 25 volts. Several energy storage capacitors are used which are charged to voltages between 17 and 21.5 V. In the published European patent application 0 731 003 A1 an electric circuit is disclosed in which several 25 V energy storage capacitors is replaced by one single 63 V capacitor used for several safety devices in motor vehicles.

In the published European patent application 0 546 450 A1 a system comprising an electric generator directly connected to a shaft of a safety belt roller is described. The generator converts the mechanical energy from the strapping action to electric energy which is stored in a capacitor. In an emergency the stored energy is used to ignite a pyrotechnic cartridge to tension the safety belt.

In the prior art devices capacitors are used to store rather small energies. The

highest voltage mentioned in the cited documents is 63 V in a 2200 μF capacitor as described in European patent application 0 731 003. This energy, given as 2.7 J, is described as giving ample margins for more than the four devices which are driven by this single capacitor.

Prior art devices use capacitors to store rather small energies to ensure the availability of power in the case where the normal battery power has been eliminated due to cable breaks or main cable shortage due to the crash.

In the case of electrically tensioned seat belts the main power supply problem is different. Even if the battery could be situated in a protected position in the vehicle, the total power available would be too small. An electric seat belt tension system requires a very high power. If 15 cm of the belt is to be withdrawn in 25 ms using a 500 N tension in the end, the mechanical peak power required from the electric motor is over 3 kW. Systems intending to establish tensions of this magnitude using electric motors will run the motor at very high torques. This will cause substantial losses in the motors. Typically, a motor used for tensioning a seat belt will have resistive losses of over 1 kW during high tension operation. This will increase the peak power to some 4 kW. If two such units are to be connected to a 12 V battery, the required current, optimistically assuming a battery voltage of 10 V at the short peak, would be some 400 A for each unit assuming perfect power cables. If 3 V is permitted to be lost in the cables, only 7 V would be left for the motors. If another 1 V is lost in the power electronics, only 6 V is available for the motors, which require 1.33 kA to give 2.4 kW. Assuming two cables, each having a length of 2 meters, the required cross section would be about 31 mm^2, and the operation of the belt tension system would depend on the internal resistance of the vehicle battery and its terminals. A vehicle having four belts would require an even larger power.

SUMMARY

An object of the invention is to provide a safety belt tension system which can establish a sufficient belt tension within a short time and which can be activated as often as is required without the need to be maintained by replacing pyrotechnic charges or the like.

Another object of the invention is to provide a safety belt tension system which can establish a sufficient belt tension within a short time, which can be activated as often as required without the need to be maintained by replacing pyrotechnic charges or the like and which can establish this tension without requiring any preceding medium tension movements.

Another object of the invention is to provide a seat belt tension system which can create a substantial tension even if the belt slack is rather long.

Another object of the invention is to provide an electric seat belt tension system which is independent of battery resistance.

Another object of the invention is to provide an electric seat belt tension system which permits low cost semiconductor switches.

Another object of the invention is to provide an electric seat belt tension system which permits low volume energy storage.

Another object of the invention is to provide an electric seat belt tension system which is independent of external electric energy supply after a full tension command has been issued.

Another object of the invention is to provide an electric seat belt tension system which has low emissions of electric high frequency noise.

Another purpose of the invention is to provide an electric seat belt tension system which has low emissions of high frequency electromagnetic noise.

Another object of the invention is to provide an electric seat belt tension system which does not require large heat sinks.

Another object of the invention is to provide a compact electric seat belt tension system which can withstand the very high belt forces during a crash.

To meet the belt force requirements, a conventional seat belt frame is equipped with an electric motor capable of delivering peak torques of for example 8 Nm on the roller shaft. This would in a static condition provide some 400 N assuming an effective belt roll radius of 2 cm. Simulations (shown in Figs. 5 and 6 to be described hereinafter) indicates that such a motor permits the establishment of a belt force of over 400 N within 15 ms, the exact value of the force being dependent on the inertia of the motor. Since a pyrotechnic tensioner requires a very reliable crash sensor indication, the firing command is said to be issued some 12 ms after the start of the crash. If the time for making the decision can be reduced to 3 ms, the electric seat belt would have established 400 N of tension some 18 ms after the crash start, thus providing a sufficient belt tension within a time comparable to that of a pyrotechnic device.

Obviously, the motor can be activated as often as required without any need of maintenance. As will be demonstrated later (Fig. 5), it can establish this tension without requiring any preceding medium tension movements; the time required is practically independent of a preceding medium tension. Also, such a seat belt tension system can create a substantial tension even if the belt slack is rather long (Fig. 6); in a simulated case a belt slack of 20 cm exists before the belt gives any force on the passenger.

The power requirements are met by storing sufficient energy in a capacitor. This will make the seat belt independent of battery resistance. As the voltage is kept high, typically of about some 450 V, power semiconductors produced in large volumes for rectified 230 V AC systems can be used. The high voltage reduces the space required, since the energy content increases with the square of the voltage whereas the capacitance decreases linearly with the rated voltage of a capacitor. The local storage also makes the electric seat belt tension system independent of external electric energy supply after a full

tension command has been issued on the condition that power for the control system is also ensured by local storage.

As all parts connected to the stator phases of the electric motor and/or to the high voltage capacitor are contained in a shielding enclosure, the electric seat belt tension system has low emissions of high frequency electromagnetic noise.

The motor, capacitor and the power electronic circuits are designed to permit belt forces of some 400 N. Comfort belt forces of for example 2 N will cause very low losses in these high power devices. As a simplified rule, the losses in the stator windings follow the square of the applied torque. 2 N will therefore create winding losses that are some four orders of magnitude lower that the losses at full power torque.

By assembling the motor is such a way that it will be displaced by the very high belt tensions created by a serious crash, and providing cog means to lock the rotor if such a displacement should occur, the electric seat belt tension system can withstand the very high belt forces during a crash.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described by way of a non-limiting embodiment with reference to the accompanying drawings, in which:

Fig. 1a is a view of the latch side of an electric seat belt tension system before the assembly of a high power part,

Fig. 1b is a front view of the electric seat belt tension system of Fig. 1a,

Fig. 1c is a sectional view showing the tensioning side of the electric seat belt tension system of Fig. 1a,

Fig. 2 is an enlarged fragmentary view of a part of Fig. 1b showing devices to reduce the emission of emitted electric noise from the electric seat belt tension system of Figs. 1a, 1b and 1c,

Fig. 3 is a block diagram of the electric components of the electric seat belt tension system of Fig. 1a,

Fig. 4 is a block diagram of a system having a common high voltage power source for powering several seat belt tension systems,

Fig. 5 is a diagram of graphs of two simulated high tensioning sequences using the system of Figs. 1a, 1b, 1c and 2 for winding up a tight belt with and without pretension, and

Fig. 6 is a diagram of graphs of two simulated high tension sequences using the system of Figs. 1a, 1b, 1c and 2, one including winding up a belt with a 20 cm slack and the other with an initial medium tension sequence.

DETAILED DESCRIPTION

In the views of Figs. 1a, 1b, 1c and 2 a seat belt tensioning device is shown. The device comprises a frame 101 of punched and bent steel and a roller shaft 102, on which the seat belt is rolled up and from which it is unrolled. The frame 101 has a rear flat

portion 101a having a mounting hole 101b and connecting two flanges 101c and 101d, the flanges 101c and 101d projecting perpendicularly from the rear part 101a forwards, in the same direction. The roller shaft 102 passes through holes in the frame flanges 101c and 101d and is there rotatably mounted using suitable bearings, not shown. The roller shaft cooperates in the conventional manner with a roll out lock mechanism mounted in a housing 101e at the frame flange 101c shown schematically as a block 103 in Fig. 1a, the frame flange 101c and the housing 101e and parts located therein forming the latch side of the system. The roll out lock or interlock mechanism 103 locks the roller shaft 102 against rotation in the roll out or unrolling direction in emergency situations such as in the case where the tensioning device is tilted, the device is accelerated above a certain limit or the rotational speed of the roller shaft in the unrolling direction is above a predetermined limit. Such rollout locking mechanisms are well known and have been mounted in millions of cars for several decades of years.

Fig. 1a is basically a sectional view taken along the line A-A of Fig. 1b but has been simplified by not showing portions of a power electric and electronic part 104 mounted to the other frame flange 101d and not showing the roller shaft 102. Then an electrical connector 105 and an opening 106 in the latch frame flange 101 c, through which opening the connector is available, are easily visible. At the place of the roller shaft 102 a belt shaft position transducer 107 is visible. The latch side shown in Fig. 1a can be regarded as substantially a conventional safety belt mechanical interlock device having in addition an electronic control board 108 mounted inside the housing 101e for low voltage signal processing and carrying various electronic components such as the connector 105, the belt shaft position transducer or rotor transducer 107, a signal processing unit 109 and external cabling, schematically shown at 110. The board 108 further carries a device 111 which can change its state depending on a command from the processor 109 in such a way that the interlock mechanism 103 can be forced to a locking state. In Fig. 1a the device 111 is shown as a solenoid which can affect the interlock mechanism 103 for example by forcing a body thereof sensing the position of the tensioning device from a normal position in the horizontal, low acceleration state to a tilted state. Only the most important components mounted to the circuit board 108 are shown in Fig. 1a.

The electric and electronic power part 104 of the tensioning device is visible in Figs. 1b and 1c. Fig. 1c shows the tensioning or power side of the safety belt tensioning device and corresponds to the section line A-A in Fig. 1b. The electric and electronic power part or housing 104 at the side of the power side flange 101d is shown to enclose components which are either presently commercially available or for which development work based on similar designs are being performed and thus will be available in a near future. A compact electric stator/rotor assembly 112 forming an electric motor is directly attached to the frame flange 101d and is capable of delivering a peak torque of the order

of 9 Nm. It can be a type similar to motors made by the company High Density Drives, Stockholm, Sweden. A motor current control unit 113 which basically has a switching function is located in a compartment in the power housing 104 above the electric motor assembly 112 and has on one side, the right side in Fig. 1c, high voltage, high current terminals connected to the three-phase motor 112 and to a high voltage power source and is operative to connect these terminals to each for energizing the motor assembly. On the opposite side, the left side as seen in Fig. 1c, low voltage power input and control signal connections are provided. Such a current control unit having dimensions as shown in Figs. 1b and 1c of 31x79x8 mm is the power module "PS21102" and is capable of switching electric currents of up to 20 A at voltages of up to 600 V. The power module PS21102 has been announced by the company Mitsubishi Electric to be comprised in their DIP-IPM series of Application Specific Intelligent Power Modules.

However, the PS21102 power electronic package shown in Figs. 1b - 1c is not quite suited to the requirements when driving an electric motor of an electric safety belt tensioner device. It is drawn in the figures since it contains most of the functionality required and gives a good indication of the space or volume required by a motor current control unit. A power device useful for a safety belt tensioner device could operate with a lower current rating, e.g. with a current of about 10 A instead of the 20 A allowed by the PS21102, but would require some added functions. Thus, a DC/DC converter should be included and connected to charge a high voltage energy storage capacitor 114 from the power supply of the vehicle such as from a conventional +12 V lead acid accumulator, not shown. To permit a good control of the motor current, a motor current sensing device should also be provided in the motor current control unit 113. The total volume of such a specially adapted control unit is assumed to be equal to or smaller than the PS21102 device shown.

The electric energy required to drive the electric motor 112 is stored in the capacitor 114 which is located above the motor assembly 112 and has e.g. an elongated shape such as a cylinder with its longitudinal axes perpendicular to the rotation axis of the roller shaft 102 and of the motor assembly. The capacitor 114 may be a 330 μF 450 V capacitor from the SMH series marketed by the company Nippon Chemi-Con having dimensions as shown in Figs. 1b and 1c of 30 x 50 mm^2. A discharge of 330 μF from 450 V to 200 V will release some 25 J, which is sufficient to power a belt tensioning device which can wind up 9 cm of a belt with a final tensioning force of some 450 N. A 50 mm long capacitor having a diameter of 35 mm is capable of storing 35 J for a capacitance of 470 μF. The use of a rather high system voltage permits the use of IGBT transistors in the motor control unit 113 which are already produced in large volumes for household applications, etc. IGBT transistors working at high system voltages are capable of switching more power than MOS transistors having the same silicon area.

The power electric and electronic parts are located inside the housing 104 which is open to the right side as shown in Fig. 1b and which at a part of its opposite side is attached to the power side flange 101d. The housing is made of a material which has a high attenuation of high frequency electro-magnetic radiation which results from the very rapid voltage transients caused by the switching transistors such as IGBT transistors and could for example be made from die cast aluminium. The housing 104 has a large circular opening for the motor assembly 112 and thereabove a deep cavity or compartment 115 accommodating the motor current control unit 113. The compartment 115 extends on both sides of the frame flange 101d, on the left side up to the latch side flange 101c. The power electronic unit 113 is assembled on two circuit boards 116a, 116b which are supported by tracks 117 in the walls of the compartment 115. The circuit boards 116a, 116b could be located in substantially the same plane having adjacent edges in center of the compartment. One circuit board 116a is intended for low voltage signals and the other circuit board 116b is intended for the high power currents and high voltages. The compartment 115 is as shown in Fig. 1b at the top limited by a horizontal wall 118 against which the power electronic unit 113 is pressed. The pressure is arranged by a slight deformation of the two circuit boards 116a and 116b. Since the heat generating parts of the power electronic unit 113 have a low thermal impedance against its top surface as shown in Figs. 1b and 1c, the upper wall 118 acts as a heat sink for the power control unit 113.

Between the cavity for the motor 112 and the cavity for the capacitor 114 openings, not shown, are provided permitting electric leads from the stator of the motor 112 and from the capacitor 114 to be connected to the high voltage circuit board 116b. At the top of the housing, a cavity or compartment is arranged for the capacitor 114. Thus, the capacitor 114 and the motor assembly 112 are both located at a distant side of the power side flange 101d. All cavities in the power housing 104 are covered by a common flat lid 119. The motor windings and the power electronic parts are thus all located in spaces which are substantially closed not allowing electromagnetic emissions as will be described in more detail later.

In the frame flanges 101d, 101c interior cogs 120 and 121 respectively are punched at the periphery of the holes for the roller shaft 102. The cogs 121 are used for the operation of the conventional interlock mechanism 103 as described above and shown schematically as item 103. The cogs 120 are used to lock the right side of the rotor of the electric motor assembly 112 in the case of a crash. The motor 112 stator is rigidly inserted in the motor cavity of the power side housing 104. However, the housing 104 is attached to the frame 101 only by four pins 122 moulded into the housing 104. During a crash, the belt, schematically drawn as the line 123, is pulled by a high force. A few teeth of the interlock mechanism 103 will engage some of the teeth 121. During a serious crash, approximatively half the total force on the roller shaft 102 will pass through the

bearing, not shown, of the roller shaft at the motor or power side to the housing 104 and further through the pins 122 to the frame flange 101d, supposing that the bearing is mounted in the housing 104. If this force surpasses the break limit of the pins 122, the pins will break or bend. The whole belt shaft 102 will in that case tilt downwards, as seen in Fig. 1c, so that teeth, not shown, moulded in the belt shaft 102 engage the teeth 120 in frame flange 101d. This will ensure a sufficiently rigid locking of the belt rotor shaft 102.

Fig. 2 is an enlargement of a portion of Fig. 1b and shows an arrangement to reduce the emission of high frequency electro-magnetic radiation or "noise" from the high power electronic components. The connector 105 on the latch side mates with a connector 126 attached to that end of the low power circuit board 116a which is located in the roller shaft end of the compartment 115 for the power control unit 113. This connector pair passes through the opening 106 in the frame flange 101c, see Fig. 1a. The projecting portion of the housing 104 in which the power electronic circuits are located is arranged to fit into the opening 106. The distance shown as 125 in Fig. 2 can be closed by an electrically conductive seal, not shown. To reduce the transfer of high power electro-magnetic radiation through the connector 126, an attenuating unit 124 is provided which may be a ferrite block having separate holes for each connector pin.

To protect the electric parts from corrosion and electric malfunctioning due to condensed water, the parts in the housing 104 may be soaked in an insulating resin. Alternatively, the cavities, except the volume used for the rotor of the motor assembly 102 and its bearings, may be partially or completely filled with a potting compound.

The noise level experienced by the circuit board 108 carrying the main processor 109 can then be assumed to be low. This permits a wide selection of technologies for the angular transducer device 107. Hall element, magneto-restrictive and optical slotted or reflective sensors are among the alternatives. The required resolution is low and can be limited to the information required for commutation of the electric motor 112.

The interlock mechanism forcing device 111 has three purposes. One purpose is to lock the belt roller shaft 102 during power off. A conventional safety belt has a spring which always acts to turn the roller shaft in the roll-in or rolling-up direction. During actual use, this conventional spring action can be replaced by a small torque delivered by the motor 112. Such an arrangement is not suitable for an electric belt when parking the vehicle since this would cause a constant current drain from the battery. By arranging the device 111 to lock the safety belt roller shaft in its no-current state, the belt will stay in its start position until the processor 109 is activated by a bus command, for example initiated by the ignition key.

An alternative solution to keep the belt in place during power off is to keep a friction device against the belt roller and restricting the friction device so that it will not be effective until the last, the two last or the last few turns of belt are rolled up on the

roller. Such a device is illustrated as the spring 127 shown in Fig. 1a and mounted to the rear frame part 101a.

Another use of the forcing device 111 is to activate the unrolling lock in medium tension situations. If a pre-crash system detects a condition that merits a medium belt tension, the belt motor 112 can be set to apply a medium torque and the device 111 can be deactivated thereby activating the interlock mechanism 103. The belt motor can then maintain its torque until the belt movement has stopped, which is sensed by the angular transducer 107, and until the release time of the device 111 has elapsed. The torque can then be withdrawn. This permits the motor 112 and the power electronic device 113 to only give a substantial torque during short periods of time. This reduces the heat sink requirements of both the motor and the electronic circuits. To maintain the tension if the person body moves, the torque can be applied again after a suitable interval. If the belt then moves, the torque can be withheld until the belt movement stops again.

Yet another purpose of device 111 is to give an early locking of the belt during a maximum tension cycle. If the belt tension during the beginning of such a cycle is low, the belt roller shaft 102 will obtain a very high acceleration and reach a high speed. This will cause mechanical energy to be stored in the inertia of the motor rotor, in the belt roller shaft and in the moving part of the belt. This energy will be converted to an extra tension in the belt, and the peak tension of the belt will therefore often be higher than that derived from the torque of the motor 102 in a static test. As this might cause the force from the belt to give an unrolling torque far higher than that of the motor 102, the belt roller would get a high acceleration in the unrolling direction.

If the belt roll-out locking mechanism 103 operates in the conventional manner, it will cause a belt lock after some delay. First the belt roller must reach a minimum unrolling speed, and thereafter there is a delay until the mechanical parts have established a locking state. This will cause some unrolling of the belt and thereby reduce the tension in the belt during the following crash. By means of device 111, the belt roll-out locking mechanism 103 might be enabled before the roll-in movement is finished and can therefore establish a faster lock-up at the end of the roll-in phase, thus keeping a higher belt tension.

The storage of mechanical energy in the moving parts of the belt, the motor and the shaft is often advantageous. In order to establish specified medium tensions, this effect can be unwanted. To avoid this, the processor can employ a speed regulating operation. There are many policies possible for such an operation. Basically, the motor torque is reduced when the speed exceeds some predetermined limit.

Fig. 3 shows a block diagram of the electric components of the safety belt tensioner device shown in Figs. 1a, 1b, 1c and 2.

Power is taken from the normal vehicle electric system 301 such as a 12 V DC system. The processor 109 may communicate with the other part of the safety system

through a communication bus 302 such as "CAN". This limits the required wiring to power and communication bus, which is the common minimum for a cable to a bus connected device in a vehicle. The cable 110 can therefore in many cases be limited to 3 to 4 individual wires or leads.

To permit operation even after the vehicle power supply 301 has been interrupted due to a crash, an energy storage 303 is required for the processor 109. As the power level is low, e.g. some mA, and the time of operation is short, e.g. some 10 ms, the energy required is in the order of μJ and can be stored in a small capacitor connected to a diode preventing a short-circuited vehicle supply from short-circuiting the capacitor. Alternatively, power to the processor can be obtained from the energy stored in capacitor 114.

The DC/DC converter 304 charging the motor energy storage capacitor 114 does not need to provide more power that what is required to maintain belt tension during normal ride, typically a few Watts, and to permit an acceptable charge-up time for the energy storage capacitor 114. As it requires a switch that sustains the high voltage of the motor energy storage capacitor 114, in the embodiment shown, some 450 V, it should be integrated into the power electronic package 113.

The motor driver 113 gets high voltage power from the capacitor 114 and current control commands from the processor 109. It supplies current to the normally three phase motor 112 and feeds information on the voltage of the capacitor 114, the motor currents and the status of failure detectors for device temperature and supply voltages back to the processor 109.

For commutation purposes, i.e. to decide the correct current for each phase of the DC motor 112, the processor 109 needs information on the position of the motor rotor. This information can be obtained from the transducer 107 sensing the angular position of the roller shaft 102 and thereby of the rotor, since the rotor is rigidly attached to the roller shaft.

<u>Common high voltage power source</u>

The embodiment shown in Figs. 1a, 1b, 1c, 2 and 3 uses local energy storage. This offers several advantages. Each belt unit is complete and requires only the minimum cabling for a bus connected device. All high voltage parts are inserted in a small conductive case and thereby extremely unlikely to get in dangerous contact with humans. All parts being exposed to high speed high voltage transients are kept in a shielded box, thus reducing EMC emissions.

However, also some disadvantages exist. If the system is to be capable to wind up long belt lengths and/or to give very high belt tension, the size of the energy storage capacitor may make the safety belt unit larger than what is acceptable for the local space available in a car.

Fig. 4 shows an embodiment having distributed smaller capacitors 114 for each belt

unit, and a complementary common energy storage 402 fed by a DC/DC converter 401. The voltage on the local units are kept somewhat higher than for the common supply. This will keep all diodes 403 in their non-conducting state. It will in turn create a high effective impedance between the local supplies 114 and the common supply 402. This is relevant since even small torques supplied by the local belt motors to maintain a minimum belt tension will create much electric noise on the local energy storage capacitors 114. As long as the diodes 403 are in their high impedance state, this noise will only have a high impedance path out to the connection cables like 404. The EMC requirements on the cabling can thereby be reduced since high noise will only be introduced when the safety belts perform belt tensioning operations which require enough energy to lower the voltage of the local capacitors below that of the common supply. The cables 404 should however be screened with the screen at chassis potential and could be coaxial.

Yet another solution would be to reduce the local capacitors to the level required to keep the local high voltage level stable enough for the power electronic devices and delete the diodes 403 and the local DC/DC converters 304.

<u>Full tension combined with earlier medium tension action</u>

Fig. 5 shows simulations of belt tension arranged by the embodiment shown in Figs. 1a, 1b, 1c and 2. The force build-up is strongly dependent on the characteristics of the belt, the clothing and the person in the seat. The simulation shows the force for the assumption that the belt can be regarded as a linear force spring with 500 N for every 10 cm reduced free belt length. Two examples are given; a first one starts with no belt tension and the second one with an initial tension of 70 N. The simulations indicate a very quick response which is practically independent of whether the initial tension is 0 or 70 N. The force is built up by the electric motor 112; the force in the belt is maintained by the belt roll-out locking mechanism 103, assumed to be enabled already at zero belt roller speed by the forcing device 111.

Fig. 6 shows two more simulations of belt tension arranged by the same embodiment. One simulation shows the force for the assumption that the belt can be regarded as a linear force spring with 500 N for every 10 cm, but in this case with a 20 cm slack. This simulation indicates an acceptable end force and response time for a belt slack that would create no pretension at all for most pyrotechnic devices. The other example shows a scenario where a warning message is given by the application of a medium tension of some 125 N. At the 47th millisecond a full tension command is given. As can be seen, the initial warning will reduce the following full tension force. This is because the energy in the capacitor is partly wasted in the initial warning sequence. The force is built up by the electric motor 112; the force in the belt is maintained by the belt roll-out locking mechanism 103, assumed to be enabled already at zero belt roller speed by the device 111.

Example of seat belt operation

The behaviour of the seat belt tensioner device depends on the software in the main controller or processor 109 and can therefore be adjusted to fit the requirements of the vehicle manufacturer. The following example of the operation of the seat belt tensioning device refers to the belt as described with reference to Figs. 1a - 4.

When the vehicle is not used, the belt will be fully wound up on the belt roller shaft 102. It is kept in place by the spring 127 or by the belt roll-out locking mechanism 103 which is kept in a permanently locked condition by the device 111. The seat belt system will in this state not draw any electrical current, and the voltage eventually remaining in the high voltage capacitor 114 will slowly decay due to leakage currents.

The belt will be activated for example because of a door opening, a central door lock disable or the insertion of the ignition key. At this activation, the DC/DC converter 304 will start and charge the capacitor 114. The time needed therefor depends on the capacitor voltage at the time of activation and on the current load on the battery deemed to be suitable. If each seat belt is permitted to draw 1 A from the 12 V supply, the charging will take approximately 3 seconds.

In systems using the belt roll-out locking mechanism 103 to keep the belt in place when the seat belt tensioning device is de-activated, the next step in the activation sequence is to set the motor 112 to give a slight roll-up torque corresponding to a net force of for example 2 N after the effect of the belt lock weight is compensated. The motor 112 can operate even with low voltages in the capacitor 114 and can therefore be activated as soon as the capacitor is charged to some 20%. Thereafter, the device 111 is activated, thus normally disabling the belt roll-out lock 103, permitting the user to draw and unroll the belt. The processor will assume that the belt starts in its normal start position. By using information from the encoder 107, the processor 109 can calculate the effective radius of the belt. This permits the processor to cause a wanted belt force regardless of the effective radius of the belt roller 102 by adjusting the motor torque to fit the required belt force.

When the belt is rolled out by the user, the belt force can be set to a value deemed to be suitable. Assuming that there is a sensor in the belt buckle, the belt processor 109 can get information through the bus system that the user has fastened the third point of the belt. After a suitable delay, a suitable belt tension can be applied for some seconds to ensure that the belt is tightened. The belt tension can thereafter be relaxed to a very low value, or adjusted to a value requested by the user in the case where the car manufacturer has provided the car with a capability of accepting such commands.

The processor can then monitor the movements of the belt and eventually increase the force at regular intervals in the case the belt is unrolled relative to the value registered after the initial tightening after the activation of the buckle sensor. Such a policy will re-establish the belt length in the cases where the user has made temporary

movements requiring a longer belt.

In vehicles having some pre-crash sensor, the belt can be used to issue warnings by a medium level tension, for example the 125 N as shown in Fig. 6. As described above, only some types of pre-crash sensor alarms seem to be suitable for a driver alert. In some cases, for example if a vehicle in front of the vehicle with the crash sensor suddenly reduces its speed and the driver of the vehicle having the crash sensor does not seem to make any suitable actions, a driver alert can be useful and a signal through the belt gives a unique signal that a driver alert is required. Such a medium force action is also suitable for such passengers that happen to have their belt rolled out relative to the initial tightening after the activation of the buckle sensor.

Many pre-crash alarms will not reach a significant probability until a very short time before the suspected impact. Such alarms should cause a full force belt tension action.

In the end of a full force belt tension action, it might be suitable to keep the motor in a high torque state even after that the belt speed has been reduced to zero and the roll-out lock has been activated. This will reduce the voltage in the capacitor 114 to very low values, thereby reducing the risk of sparks if the housing 104 should be broken during the following crash sequence.

After a false full tension alarm, the charging of the capacitor 114 can be set at a far higher rate as the engine most likely is on and has charged the battery for some time. For example, if each seat belt is permitted to draw 5 A from the 12 V supply, to obtain a full charge will take approximately 0.6 seconds.

Assuming a buckle sensor, the motor 102 can be set to a higher belt tension, e.g. about 10 N, with a belt rolling speed depending tension reduction to ensure that the belt is rolled up as soon as the user has released the buckle switch at the end of the drive. The belt can then be locked in the end position using the devices 103 and 111. If a belt retaining spring 127 is used, a speed limited higher tension can be used and the tension can be increased when the last one or two turns are being wound up. Since most warning sequences should have a length of some 200 - 700 ms, the DC/DC converter 304 should normally have time to restore most or all of the energy lost during the warning sequence, and in such cases the final tension will be close to the normal one, as shown in Fig. 5.

Alternative embodiments

The basic concept of the invention can be implemented using other embodiments.

In the embodiment shown, the processor 109 is situated outside the high frequency attenuated enclosure 104. Even if this often is advantageous it is not necessary.

In the embodiment shown, the motor 112 is a brushless DC motor. The principles shown can equally well be used with mechanically commutated motors having a sufficient power density. In such a case, the motor current control can be achieved by a single semiconductor switch, thus reducing the size and cost of the power electronics.

The communication between the safety belt processor and the other parts of the safety system is assumed to be made through a bus system. Even if this is often advantageous, the communication can be performed in many ways, including separate wires for every signal type.

The commutation control of the motor 112 by the safety belt processor 109 uses rotor position information from an angular transducer 107. Even if this is often advantageous, the commutation can be controlled using other information such as the emf generated in the motor phases.

The motor rotor is assembled on the belt roller shaft. Even if this often is advantageous, the motor can in some cases be connected to the belt roller using intermediate mechanical elements, such as belt or cog wheels. This permits the use of a motor capable of providing a lower peak torque but adds the disadvantages of more components and a larger volume occupied by the device. The possibility to use a motor providing a lower peak torque and a higher speed is reduced due to the very high accelerations required on the belt roller shaft. The accelerations required on the belt roller surpasses the no load acceleration of many motors in the 2 - 10 Nm range. If a lower torque motor is to be connected to the belt roller shaft using the some gear box, for example with a gear ratio of 2, the motor must accelerate twice as fast as the belt shaft and be capable of delivering a substantial torque in addition to the torque required for its own acceleration.

CLAIMS

1. A safety belt tensioner for tensioning a safety belt in emergency situations, **characterized by** an electric motor and an electric capacitor connected to the electric motor and adapted to store energy for tensioning the safety belt.

2. A safety belt tensioner according to claim 1, **characterized in** that the electric motor has a driving shaft in common with a roller shaft for rolling up the safety belt.

3. A safety belt tensioner according to claim 1, **characterized in** that the electric motor and the capacitor are located at a first side of a roller shaft for rolling up the safety belt.

4. A safety belt tensioner according to claim 1, **characterized in** that the electric motor and the capacitor are located adjacent to each other.

5. A safety belt tensioner according to claim 1, **characterized in** that the electric motor and the capacitor are located within a common enclosure.

6. A safety belt tensioner according to claim 1, **characterized in** that the electric motor and the capacitor are located within a common enclosure that provides a substantial attenuation of electromagnetic noise emitted from the motor and capacitor.

7. A safety belt tensioner according to claim 1, **characterized in** that the electric motor, electronic switches controlling the electrical current provided to the electric motor and the capacitor are located adjacent to each other.

8. A safety belt tensioner according to claim 1, **characterized in** that the electric motor, electronic switches controlling the electrical current provided to the motor and the capacitor are located within a common enclosure.

9. A safety belt tensioner according to claim 1, **characterized in** that the electric motor, electronic switches controlling the electrical current provided to the motor and the capacitor are located within a common enclosure which provides a substantial attenuation of electromagnetic noise emitted from the motor, switches and capacitor.

10. A safety belt tensioner according to claim 1, **characterized in** that the electric motor is adapted to act on a first end of a roller shaft for rotating the roller shaft in a direction to roll up the safety belt and that a locking mechanism is arranged to act on a second end of the roller shaft, the locking mechanism acting to lock the roller shaft from rotating in an unrolling direction in emergency situations, in particular when unrolling the safety belt at too high rotation speeds or tilting the safety belt tensioner.

11. A safety belt tensioner according to claim 1, **characterized in** that the electric motor is adapted to act on a first end of a roller shaft for rotating the roller shaft in a direction to roll up the safety belt and that a transducer device to register the position of the roller shaft is assembled on the other end of the roller shaft, thereby reducing the electromagnetic noise close to the transducer.

12. A safety belt tensioner comprising a roller shaft for rolling up a safety belt, a locking mechanism acting on the roller shaft to lock the roller shaft from rotating in a

direction to unroll the safety belt in emergency situations and an electric motor acting on the roller shaft for rotating the roller shaft to tension the safety belt in emergency situations, **characterized in** that the electric motor is adapted to act on a first end of the roller shaft and that the locking mechanism is arranged to act on a second end of the roller shaft, the second end being opposite the first end.

13. A safety belt tensioner comprising a roller shaft for rolling up a safety belt, a locking mechanism acting on the roller shaft to lock the roller shaft from rotating in a direction to unroll the safety belt and an electric motor acting on the roller shaft for rotating the roller shaft to tension the safety belt and capable of creating large tension in the belt in emergency situations, **characterized in** that the locking mechanism is designed to enable the roller shaft to rotate in an unrolling direction only when all three of the following conditions are met: the safety belt rotation speed in the unrolling direction is low, the safety belt tensioner is not tilted and an un-lock enabling device is activated.

14. A safety belt tensioner comprising a roller shaft for rolling up a safety belt, a locking mechanism acting on the roller shaft to lock the roller shaft from rotating in a direction to unroll the safety belt and an electric motor acting on the roller shaft for rotating the roller shaft to tension the safety belt, **characterized in** that the system controlling the motor also can control the locking mechanism so that the locking mechanism can be activated to stop the roller shaft from rotating in an unrolling direction.

15. A safety belt tensioner according to any of claims 12 - 14, **characterized in** that the locking mechanism is mounted in a first housing and the electric motor is mounted in a second housing, the first and second housings being connected by an elongated connection member having electronic circuits mounted therein for controlling the electric motor.

16. A safety belt tensioner comprising a roller shaft for rolling up a safety belt, a locking mechanism acting to lock the roller shaft from rotating in a direction to unroll the safety belt in emergency situations and an electric motor acting on the roller shaft to rotate in a direction to tensioning the safety belt in emergency situations, **characterized by** a control unit controlling the electric motor to provide all of the force or torque required roll up the safety belt and to tension the safety belt comfortably around or at a passenger in non-emergency situations.

17. A safety belt tensioner according to any of claims 1 - 16, **characterized in** that the locking mechanism is connected to a forcing device operative to force the locking mechanism to act to lock the roller shaft from rotating on power-off.

18. A safety belt tensioner according to any of claims 1 - 16, **characterized by** a friction device acting with friction on the safety belt only when the safety belt is substantially rolled up on the roller shaft, the friction device acting to maintain the safety belt in a rolled up state on power-off.

19. A safety belt tensioner comprising an electric motor for tensioning a safety belt in emergency situations, the tensioner further comprising electric capacitors adapted to store energy for tensioning the safety belt in emergency situations, at least one local capacitor being located adjacent to or in the same enclosure as the motor and at least one distant capacitor being located at a distance from or remote of the motor, and further comprising interconnection leads between the capacitors, **characterized in** that the local capacitor during normal operation has a high impedance to the distant capacitor thereby insulating the distant capacitor and the interconnection leads from noise generated on the local capacitor during low power operation of the motor and that during large power operation the local capacitor obtains a low impedance connection to the distant capacitor thereby permitting electric power to flow from the distant capacitor to the local capacitor.

20. A safety belt tensioner according to claim 19, **characterized in** that the impedance is obtained by a diode and that during low power operation the voltage of the local capacitor is kept higher than the voltage of the distant capacitor, thereby blocking the diode, and that when the voltage of the local capacitor during high low power operation falls, the diode opens, thereby permitting electric power to flow from the distant capacitor to the local capacitor.

21. A safety belt tensioner comprising a roller shaft for rolling up the safety belt, a frame supporting both ends of the belt shaft, an electric motor for tensioning a safety belt in emergency situations and having a rotor mounted on an elongation of the belt shaft, **characterized in** that the shaft opening in the frame on the motor side has cogs facing the shaft and that the shaft has cogs facing this shaft opening in the frame, and that the motor is assembled to the frame using elements of limited strength, so that during normal operation the cogs on the shaft move freely close to the cogs in the frame but in case of a very heavy load on the belt, the elements keeping the motor at the frame will bend or break, thereby permitting the shaft to move so that some shaft cogs will engage with the frame cogs, thereby locking the shaft to the frame.

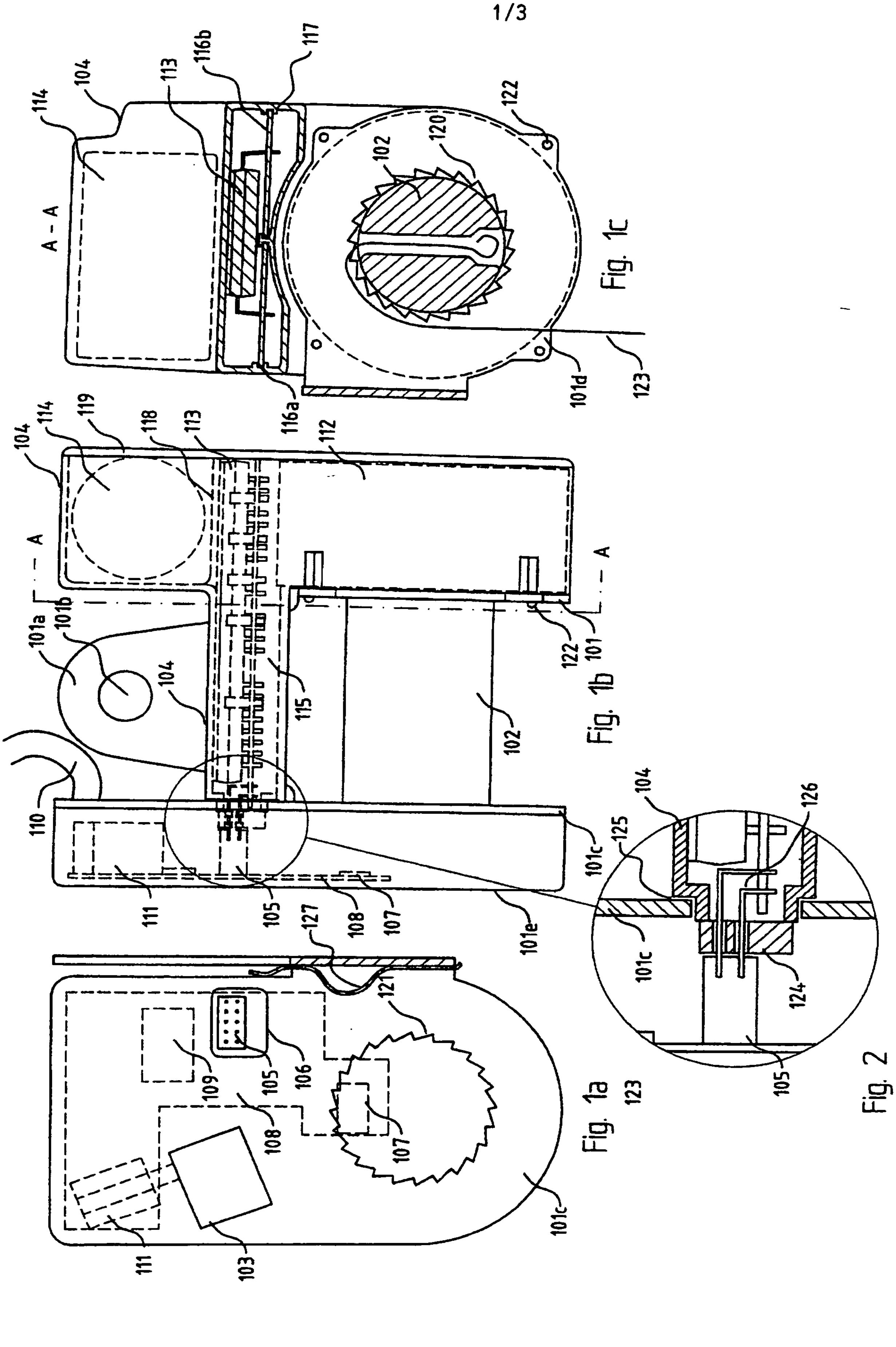

Fig. 1a

Fig. 1b

Fig. 1c

Fig. 2

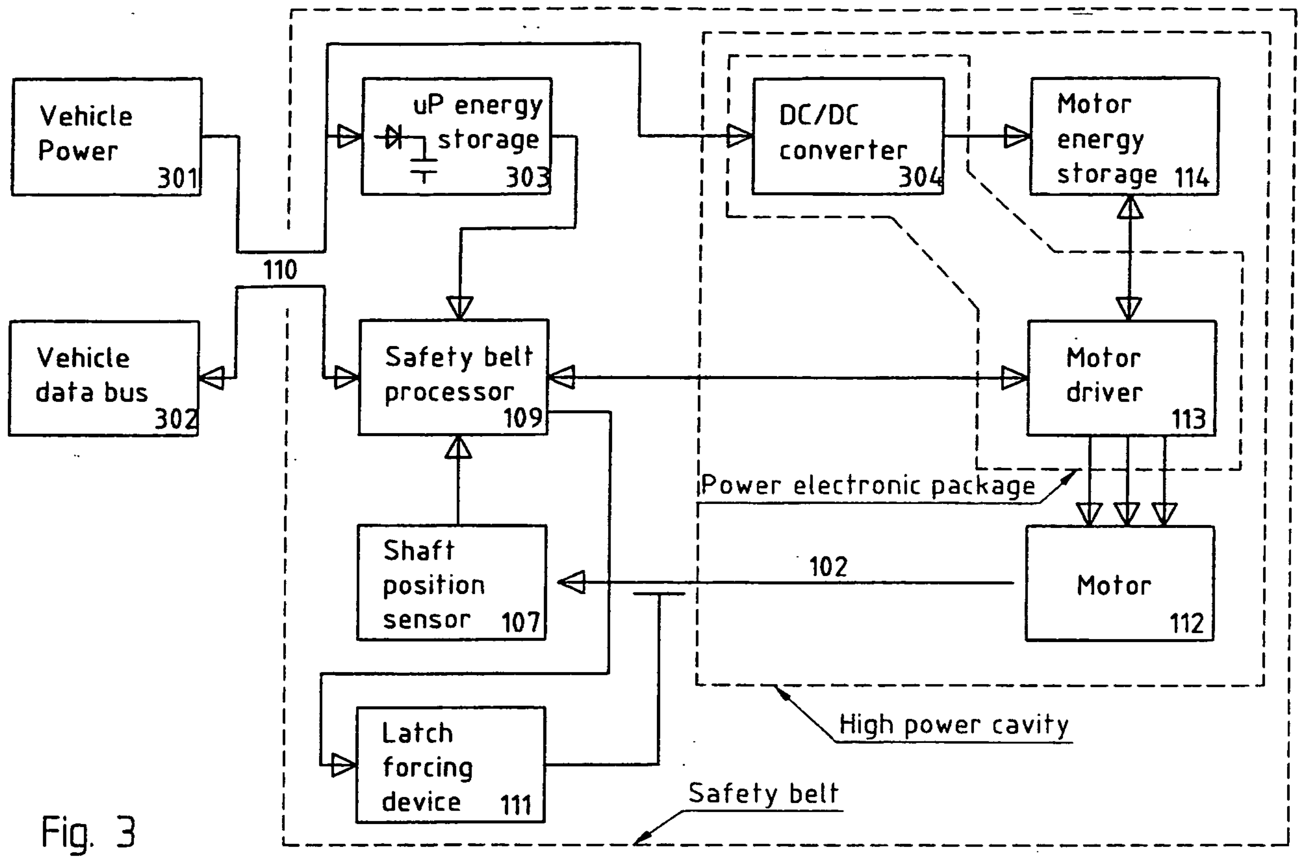
Vehicle Power 301
uP energy storage 303
DC/DC converter 304
Motor energy storage 114
110
Vehicle data bus 302
Safety belt processor 109
Motor driver 113
Power electronic package
Shaft position sensor 107
102
Motor 112
Latch forcing device 111
High power cavity
Safety belt

Fig. 3

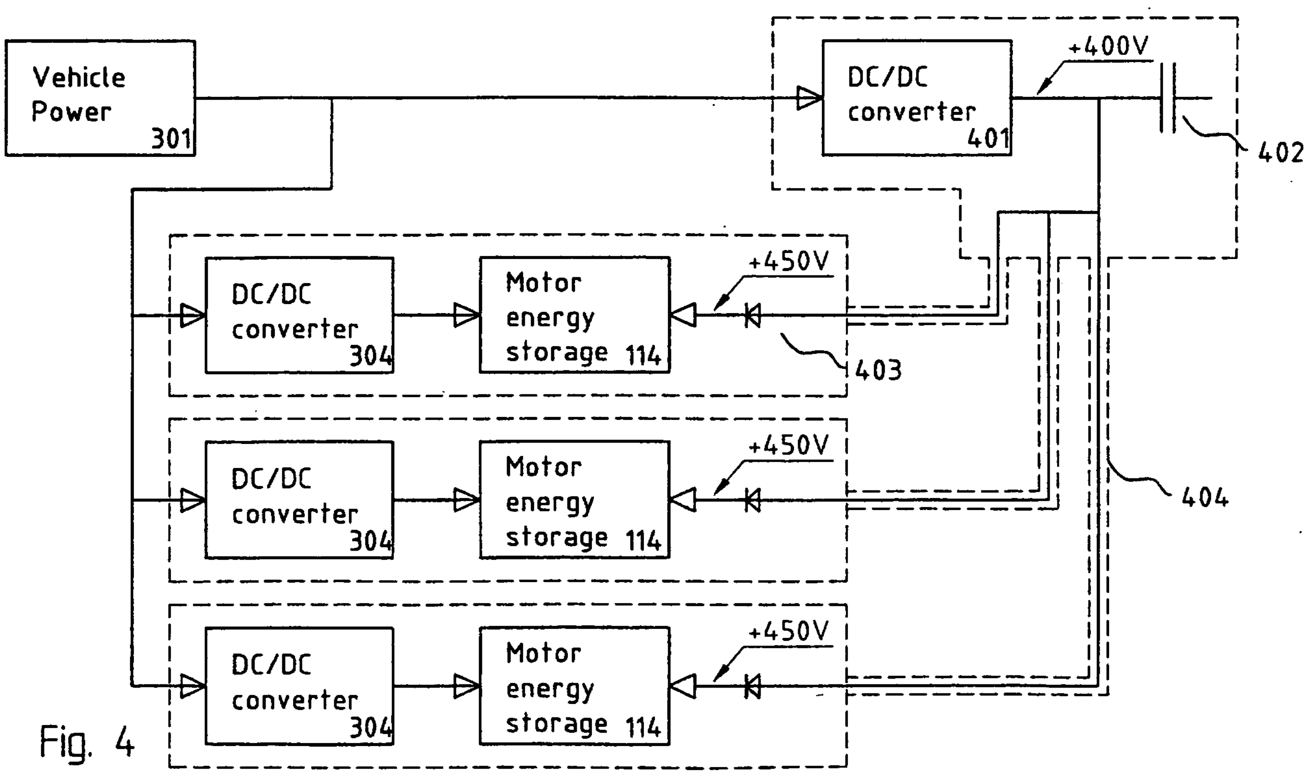
Vehicle Power 301
DC/DC converter 401
+400V
402
DC/DC converter 304
Motor energy storage 114
+450V
403
404

Fig. 4

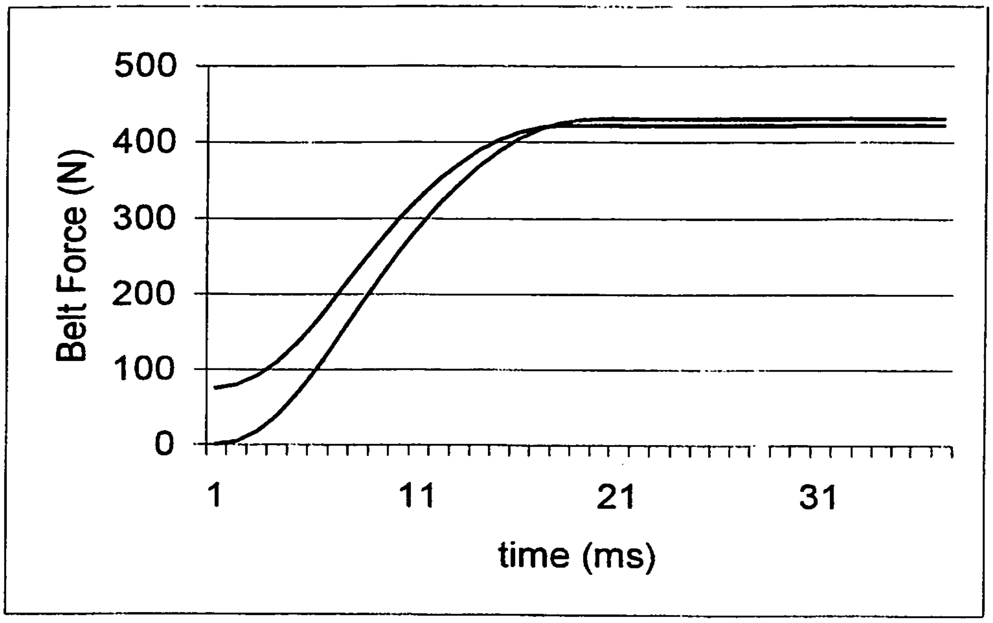
500
400
300
200
100
0
Belt Force (N)
1
11
21
31
time (ms)

Fig. 5

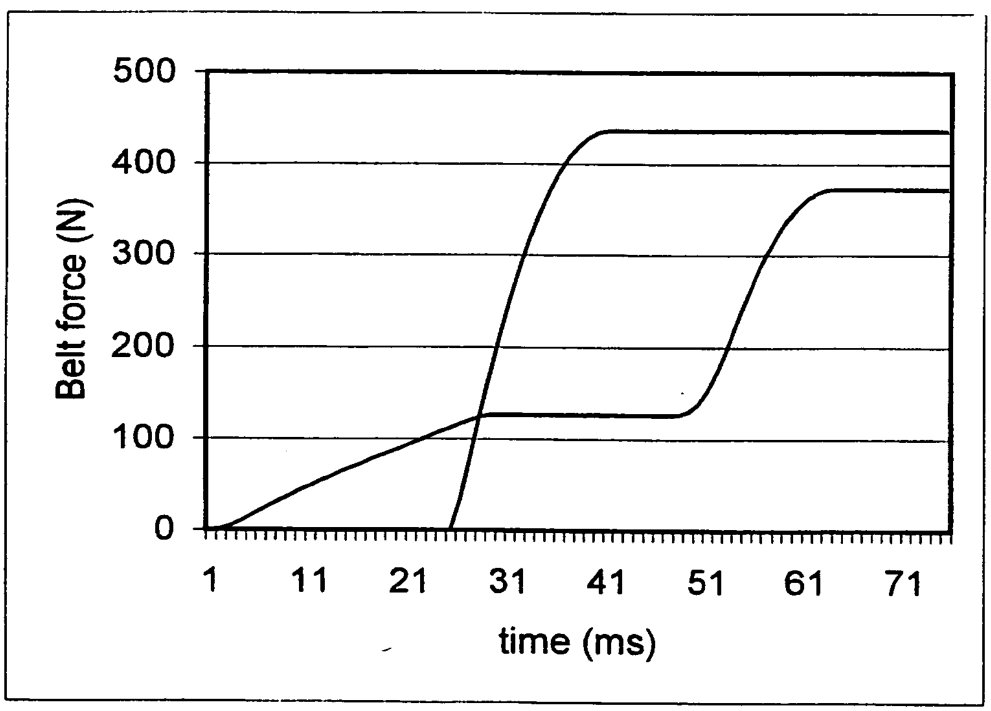
500
400
300
200
100
0
Belt force (N)
1
11
21
31
41
51
61
71
time (ms)

Fig. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 99/00571

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: B60R 22/36, B60R 22/46
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: B60R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC, WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 19636448 A1 (TAKATA CORP.), 10 April 1997 (10.04.97), figure 1, abstract	12,13,15,16
Y		14
A	abstract	1,10,19
	--	
X	US 5558370 A (LEONARD W BEHR), 24 Sept 1996 (24.09.96), column 3, line 43 - column 4, line 21	12,13,15,16
Y		14
A		1,19
	--	

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" erlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 June 1999	01 -09- 1999
Name and mailing address of the ISA Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Hans Nordström/MN Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 99/00571

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 4332205 A1 (HS TECHNIK UND DESIGN TECHNISCHE ENTWICKLUNGEN GMBH), 23 March 1995 (23.03.95), column 2, line 11 - column 3, line 49; column 5, line 60 - column 6, line 18, figure 2	13,16
A		1,19
	--	
A	DE 19520721 A1 (PARS PASSIVE RüCKHALTESYSTEME GMBH), 19 December 1996 (19.12.96)	1,16,19
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A	US 5568939 A (BRIAN K. BLACKBURN ET AL), 29 October 1996 (29.10.96)	1,19
	--	
A	WO 9836949 A1 (BREED AUTOMOTIVE TECHNOLOGY, INC.), 27 August 1998 (27.08.98)	1,19
	--	
A	EP 0546450 A1 (TRW REPA GMBH), 16 June 1993 (16.06.93)	1,19
	--	
P,X	DE 19731689 A1 (HS TECHNIK UND DESICH TECHNISCHE ENTWICKLUNGEN GMBH), 4 February 1999 (04.02.99), column 4, line 1 - line 27	12,13
P,A		1,16,19
	--	
X	EP 0218911 A2 (ALLIED CORPORATION), 22 April 1987 (22.04.87), abstract	12,13,15,16
Y		14
A		1,19
	--	

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 99/00571

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5765774 A (MAEKAWA ET AL), 16 June 1998 (16.06.98), column 3, line 23 - line 30, figure 1, abstract	12,13,16,21
A		1
	--	
A	DE 2832160 A (REPA FEINSTANZWERK GMBH), 31 January 1980 (31.01.80)	21
	--	
Y	DE 29717477 U1 (SIEMENS AG), 15 January 1998 (15.01.98), page 10, line 3 - line 19	14
	--	

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE99/00571

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

See extra sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest
☐ The additional search fees were accompanied by the applicant's protest.
☐ No protest accompanied the payment of additional search fees.

Claims 1-11, 17, 18 and 19, 20 are directed to a safety belt tensioner provided with an electric motor connected to a capacitor.

Claims 12 and 15 are directed to a safety belt tensioner provided with an electric motor and a locking mechanism acting on opposite ends of the shaft.

Claim 13 is directed to a safety belt tensioner provided with an electric motor and a locking mechanism which enables the shaft to rotate in a unrolling direction when certain conditions are met.

Claim 14 is directed to a safety belt tensioner provided with an electric motor and a locking mechanism controlled by a system.

Claim 16 is directed to a safety belt tensioner provided with an electric motor and a control unit for controlling the the force in non-emergency situations.

Claim 21 is directed to a safety belt tensioner provided with an electric motor and a movable shaft locking mechanism acting on opposite ends of the shaft.

INTERNATIONAL SEARCH REPORT

Information on patent family members

02/08/99

International application No.

PCT/SE 99/00571

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 19636448 A1	10/04/97	GB 2304540 A,B	26/03/97
		GB 2333077 A	14/07/99
		GB 9618226 D	00/00/00
		GB 9906495 D	00/00/00
		JP 9132113 A	20/05/97
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